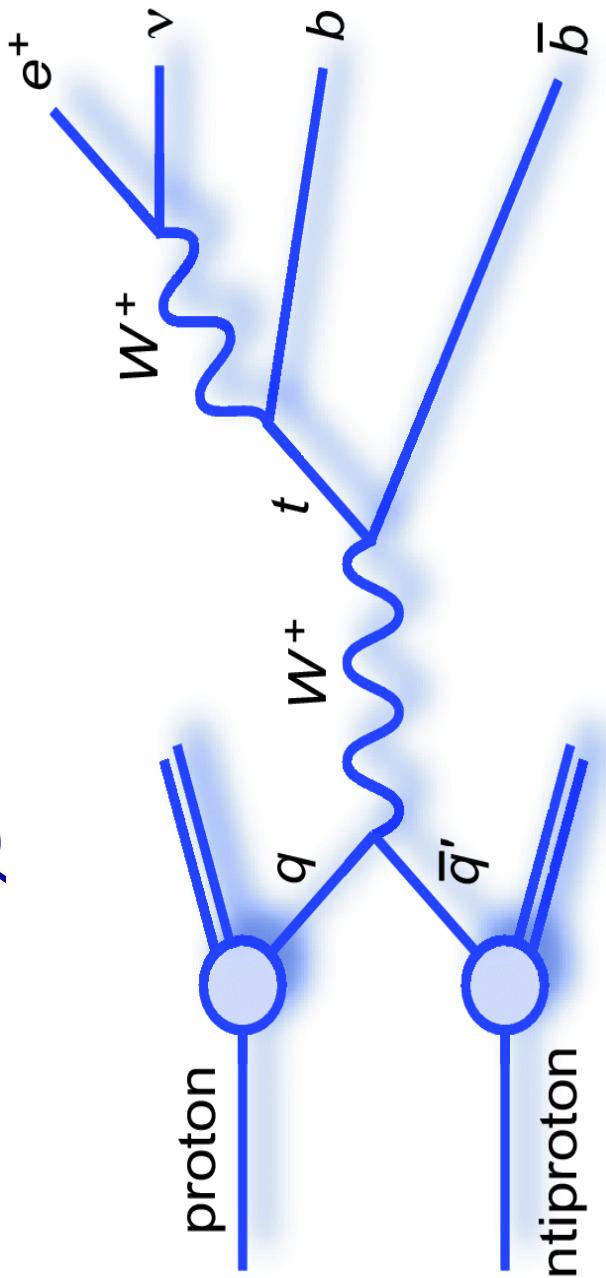


# Search for Single Top Quark Production in the Electron Channel at D $\bar{\varnothing}$ in Run II



MICHIGAN STATE  
UNIVERSITY



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on behalf of the D $\bar{\varnothing}$  collaboration

Pheno 2004, April 26-28 2004

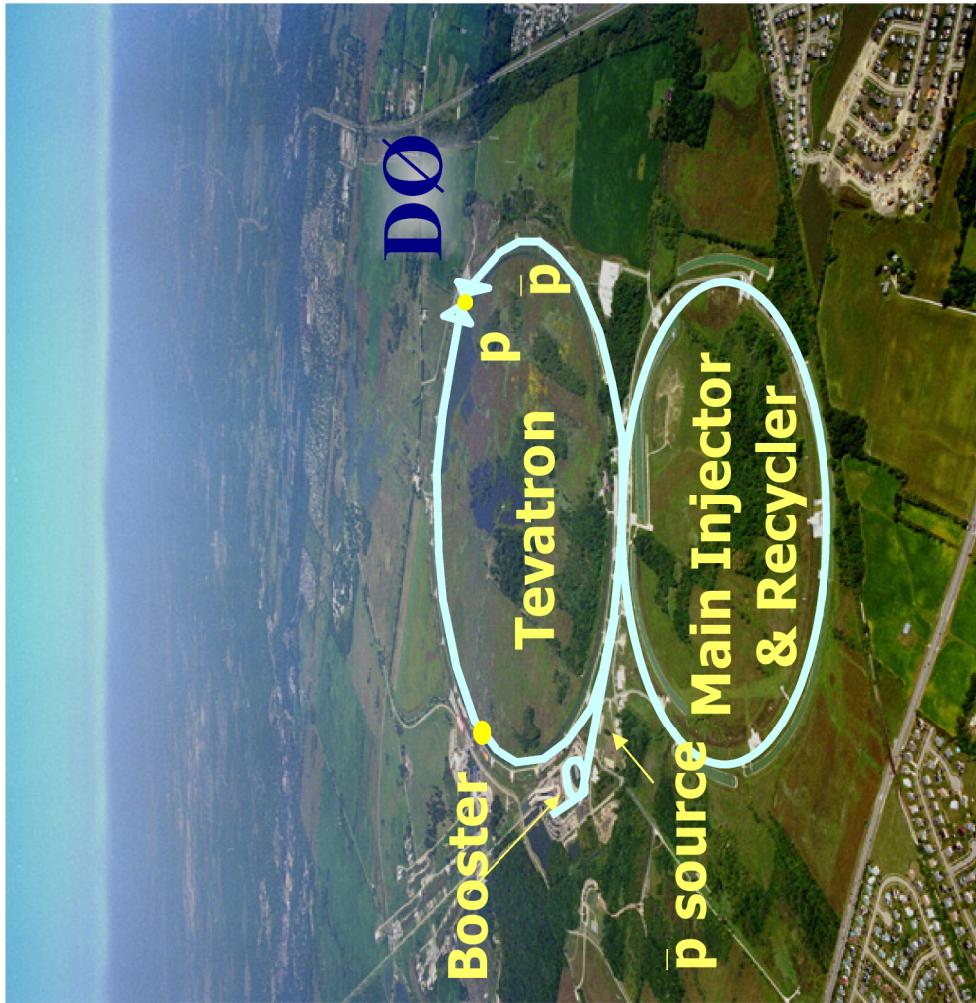
# Outline

- Introduction
  - Tevatron  $p\bar{p}$  Collider
  - Single Top Quark Production
- Experimental Setup
  - D $\emptyset$  Detector
  - Final State Reconstruction
- Single Top Analysis
  - Preselection
    - Event Yield Estimates
  - Final Selection Cuts
- Result
- Outlook



# Introduction

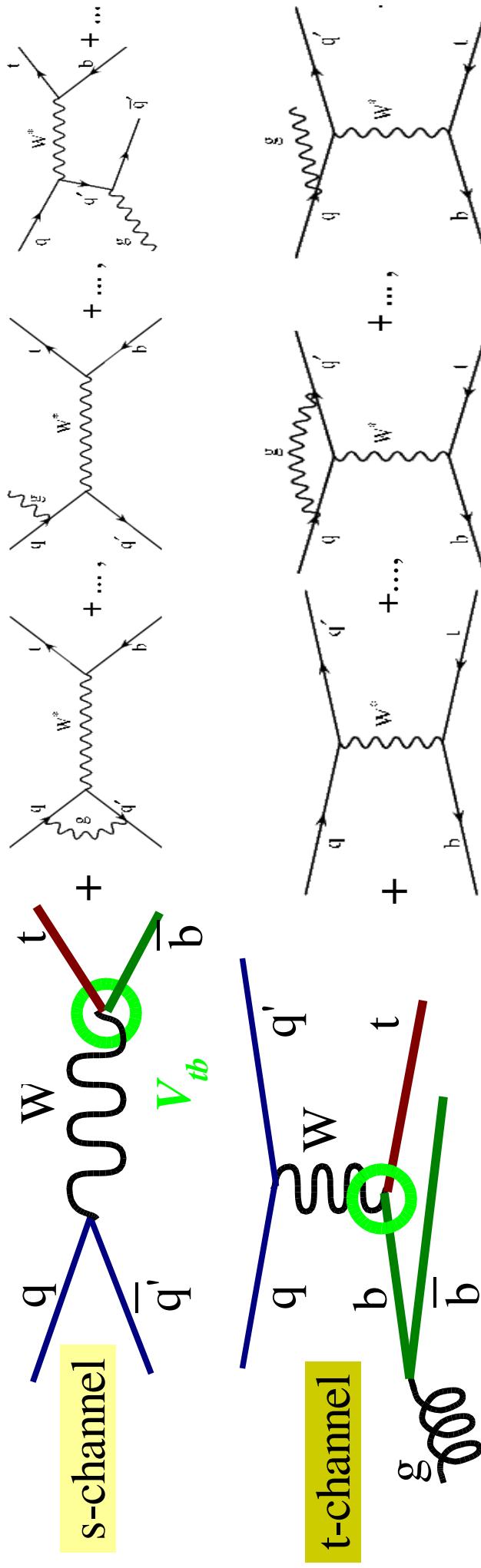
- Tevatron is the highest-energy accelerator in the world
  - Test predictions of the Standard Model in detail
  - Search for new interactions not predicted by the Standard Model
  - Only place in the world to observe top quarks
    - Observation of top quark through pair production
    - Measurement of top quark mass
- Search for interactions predicted by the Standard Model but not yet observed → Single Top Production



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# Single Top Quark Production



- Electroweak production of top

*s-channel*

$$1.98 \text{ pb} \pm 11\%$$

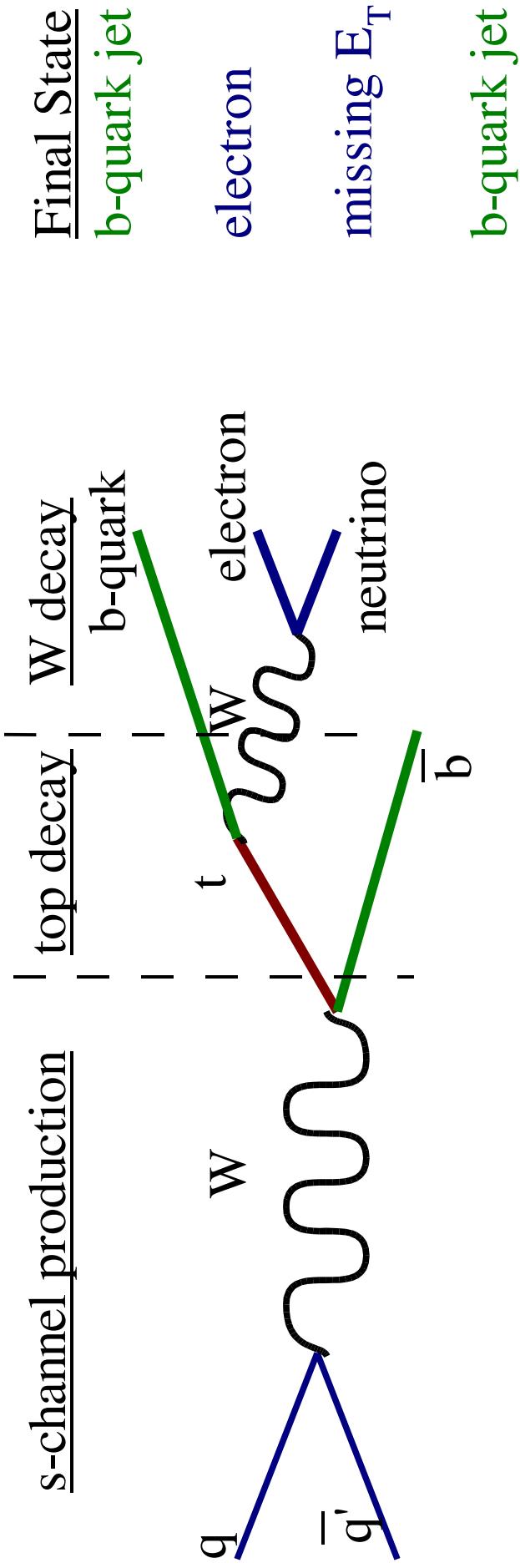
- NLO cross-sections:  $0.88 \text{ pb} \pm 8\%$
- Run I: DØ: 95% CL:  $< 17 \text{ pb}$   
CDF: 95% CL:  $< 18 \text{ pb}$

- Test predictions of the Standard Model

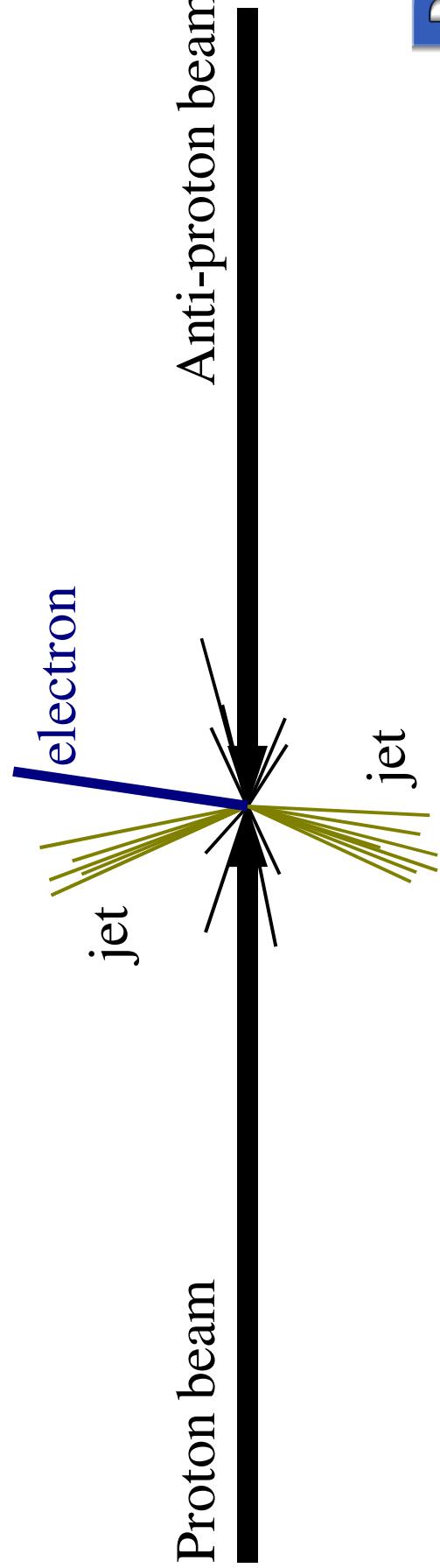
- Measure CKM matrix element  $V_{tb}$  (test CKM unitarity)
- Observe top polarization



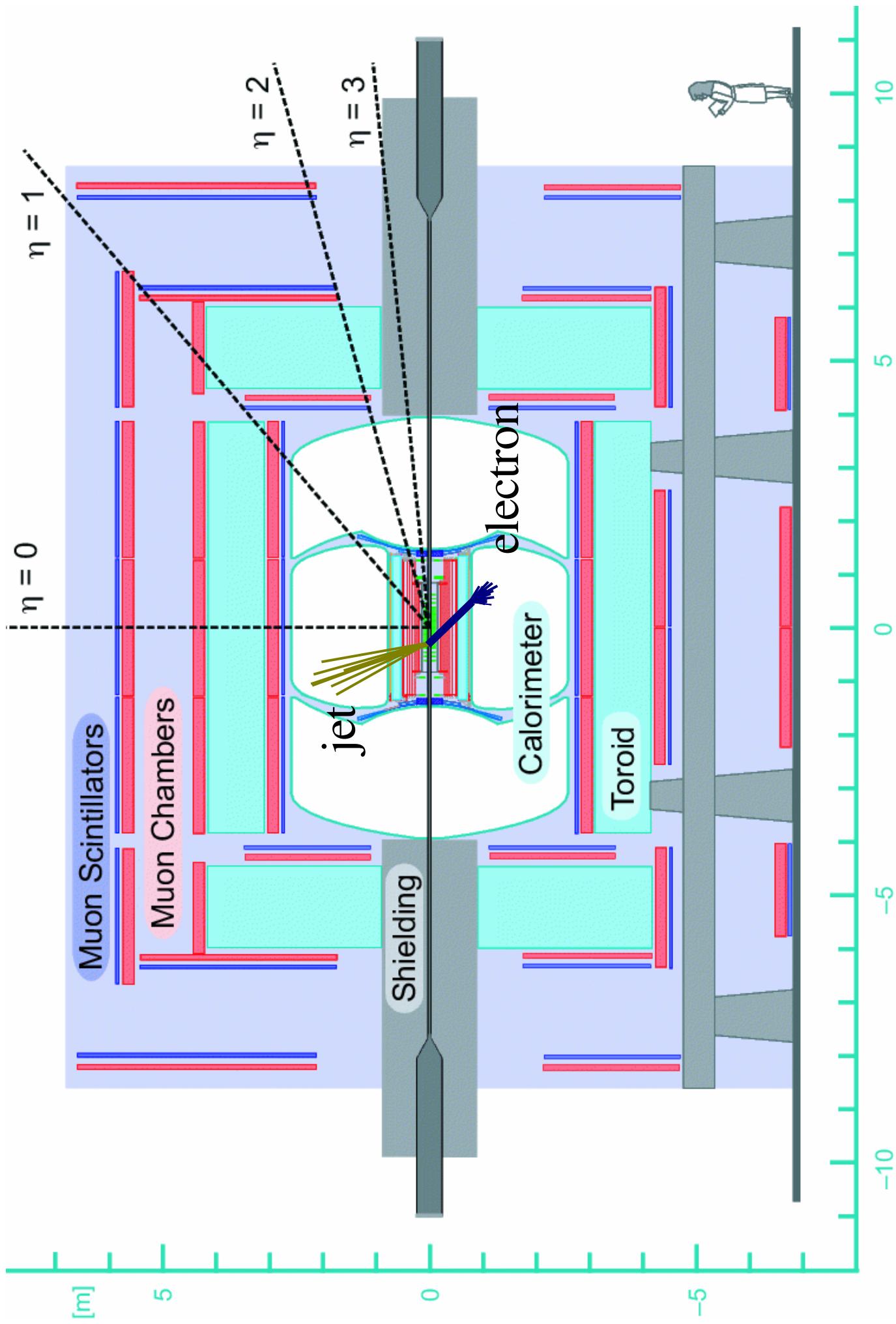
# Single Top Event Signature



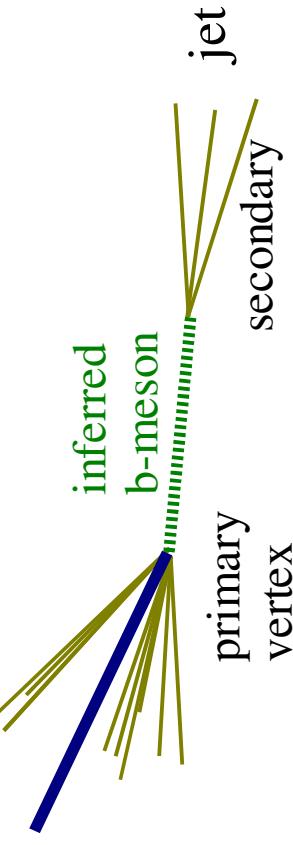
# Final State Objects



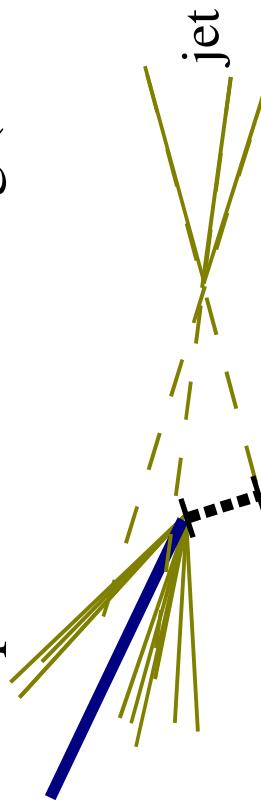
# Experimental Setup: DØ Run II Detector



# Final State Reconstruction

- Electron
  - Clustering in the calorimeter
  - Matched to central track
  - Likelihood estimator to distinguish from jets
- Neutrino (MET)
  - Indirectly through energy imbalance in transverse plane
- Jets
  - Clustering calorimeter energy
  - Corrected to get particle  $p_T$  (Jet Energy Scale)
- b-quark identification
  - Muon-in-jet from b-meson decay
    - Soft-muon tag
    - Tracking-based lifetime tagging
  - Secondary Vertex Reconstruction (SVT)
    - 

Impact Parameter Tag (JLIP)



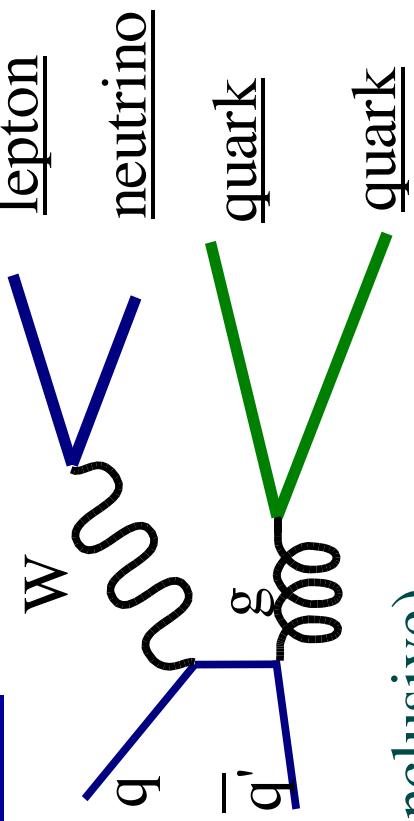
Probability for each track in the jet to originate from the primary vertex



# Backgrounds

- $W+jet$  production

- $Wjj, Wcc, Wbb, \dots$
- Estimated from data



- Normalized untagged  $W+jets$  sample by probability to tag a jet in the data (inclusive)

- Probability is derived from a multi-jet sample
- Same jet flavor composition as  $W+jets$  (within 20% uncertainty)

- Mis-reconstructed multi-jet events

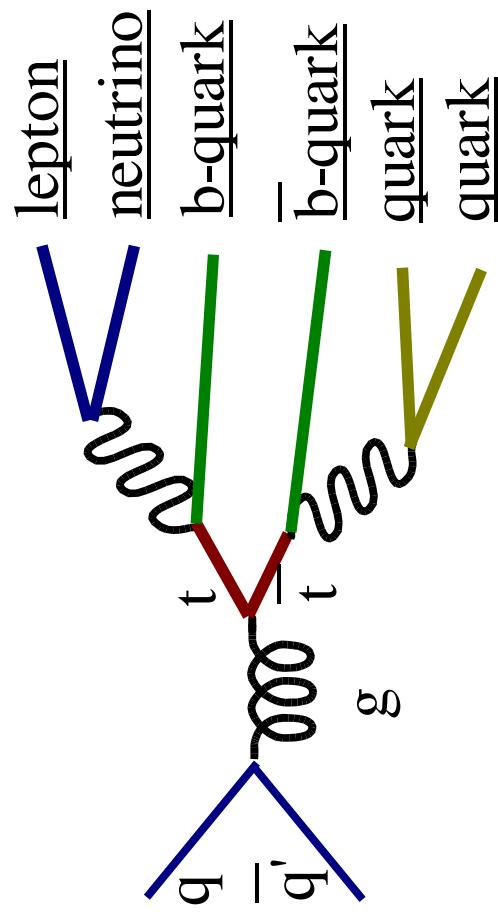
- Jet mis-identified as electron
- Estimated from data

- Top-pair production

- Lepton+jets and di-lepton
- Estimated from MC

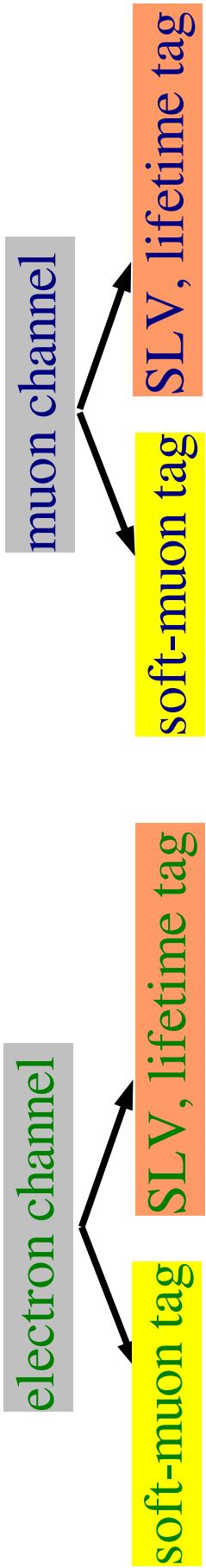
- Other ( $WZ, WW$ , cosmic rays)

- Negligible, not yet included



# Analysis Outline

## 1) Split Analysis into orthogonal channels



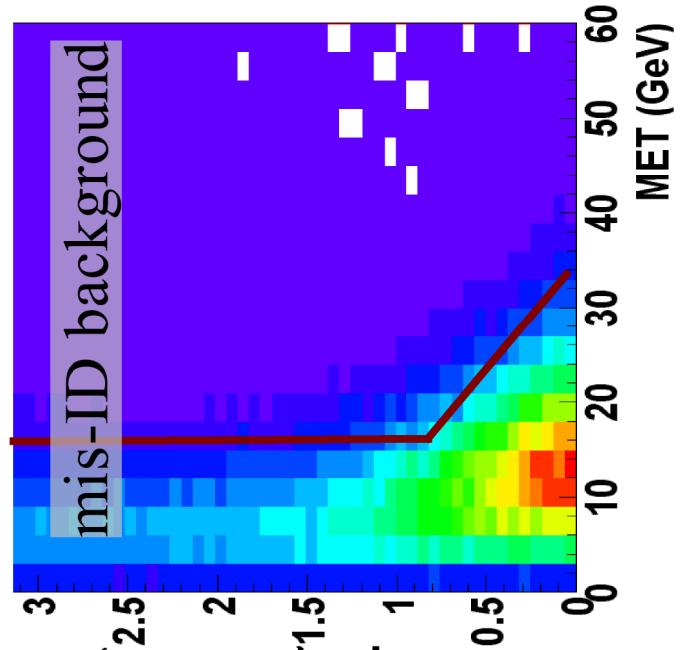
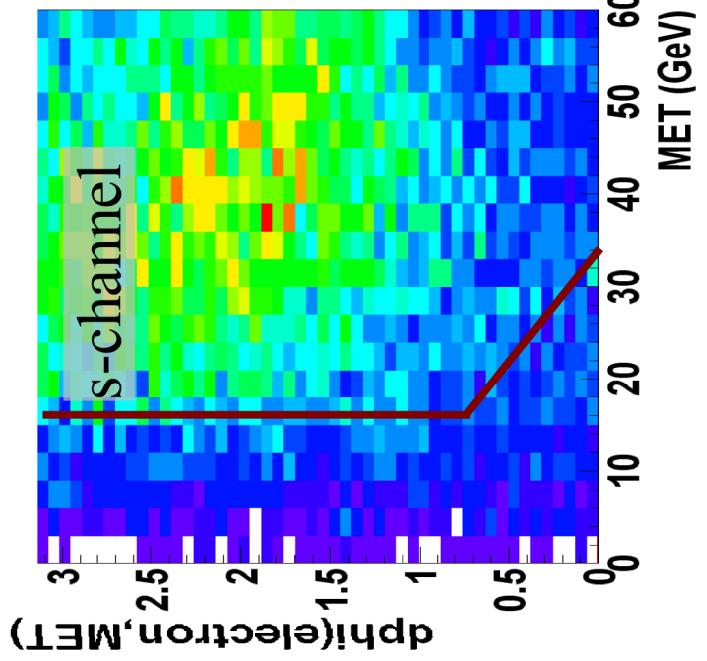
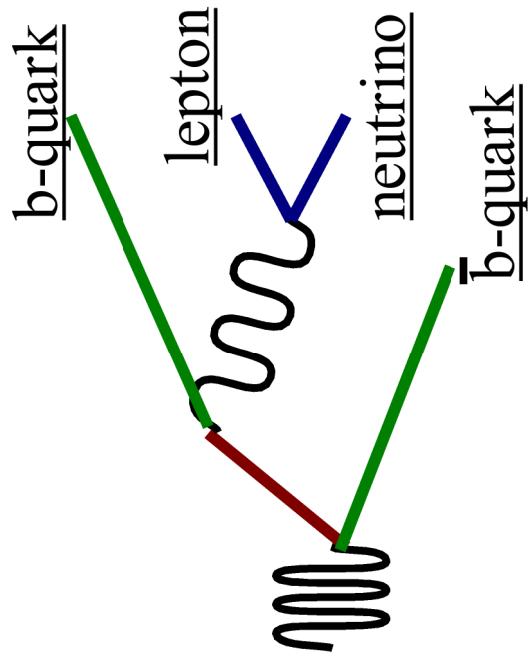
## 2) Preselection based on Single Top Event Signature

- Select events containing W and jets with at least one b-tag
  - Loose requirements to retain high signal acceptance
  - Study background estimation in detail
    - Prove that background model reproduces data
    - Reject regions of phase space that are not well modeled
- 3) Final Event Selection
  - Separate single top from backgrounds
- 4) Combine orthogonal channels for highest sensitivity

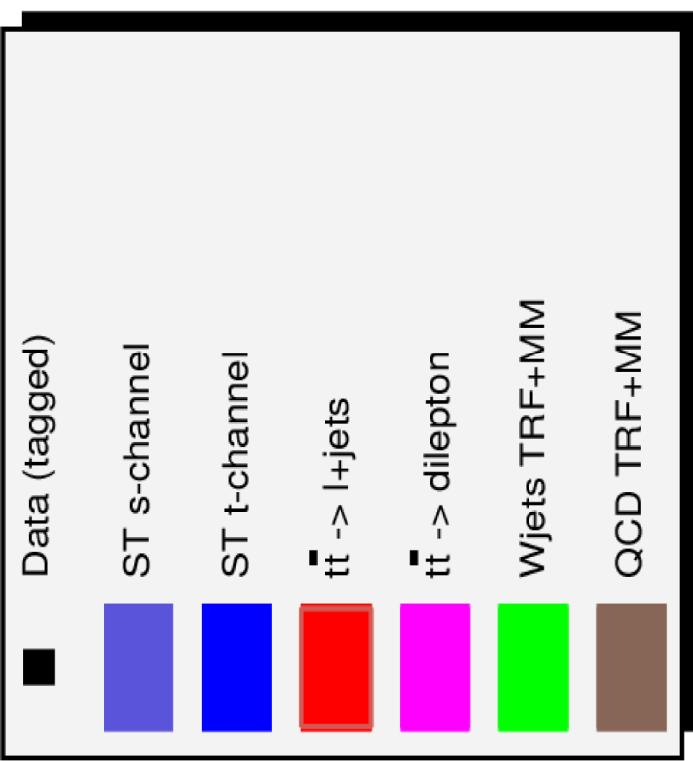
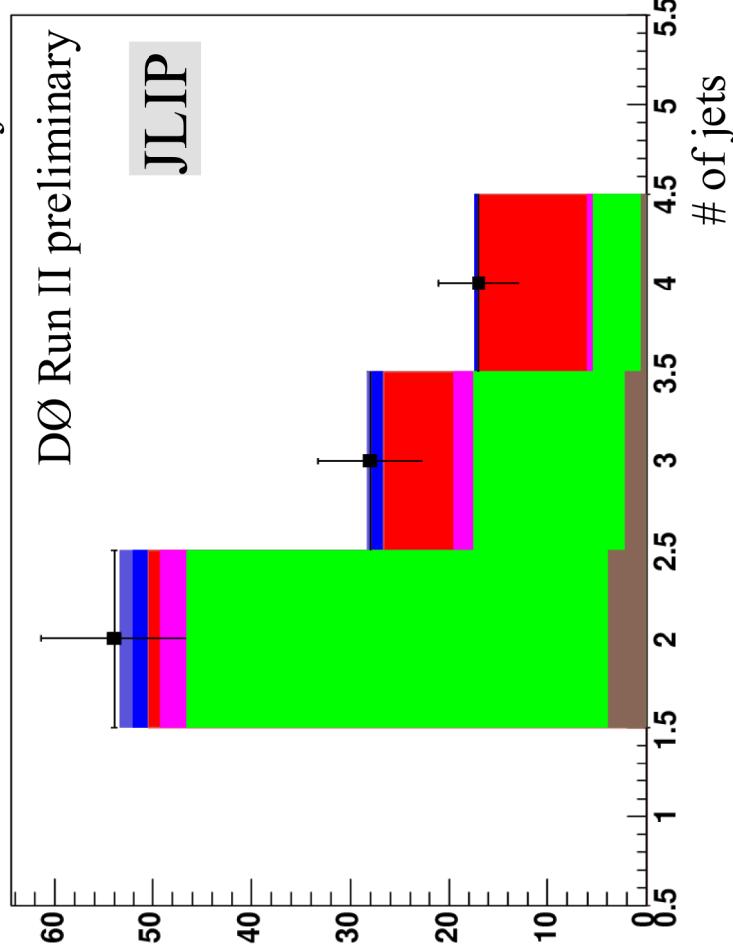
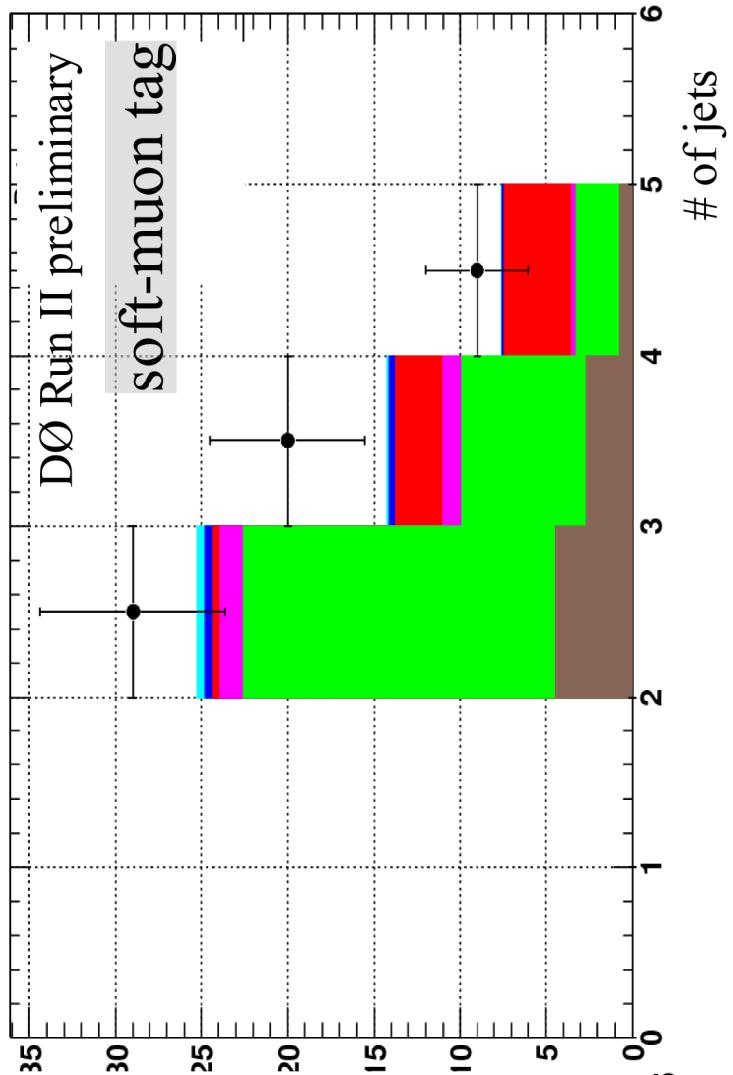
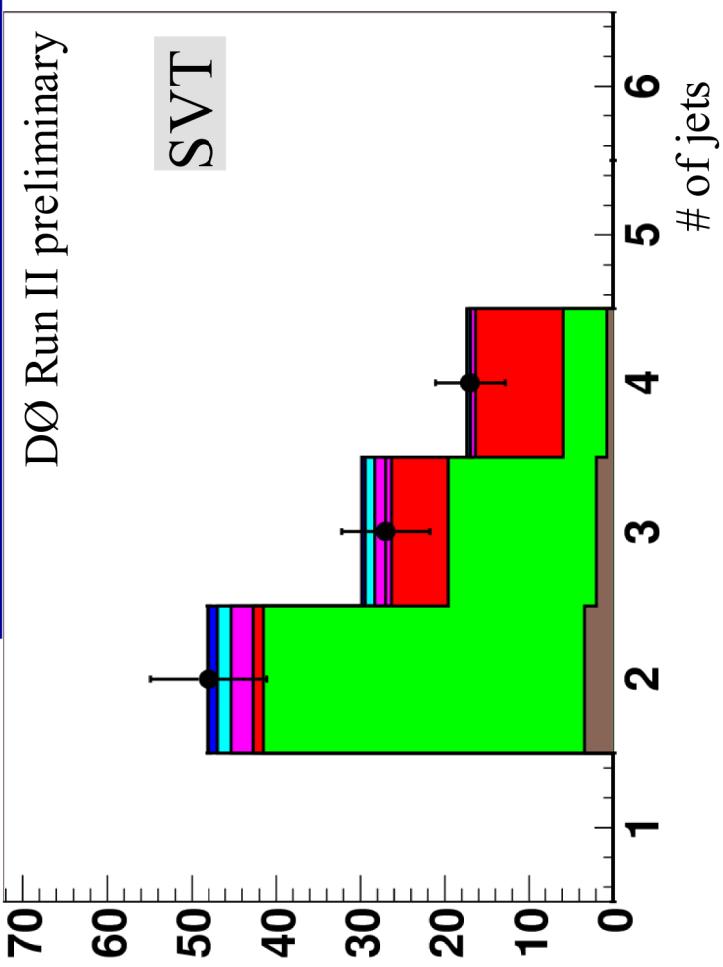


# Preselection Cuts

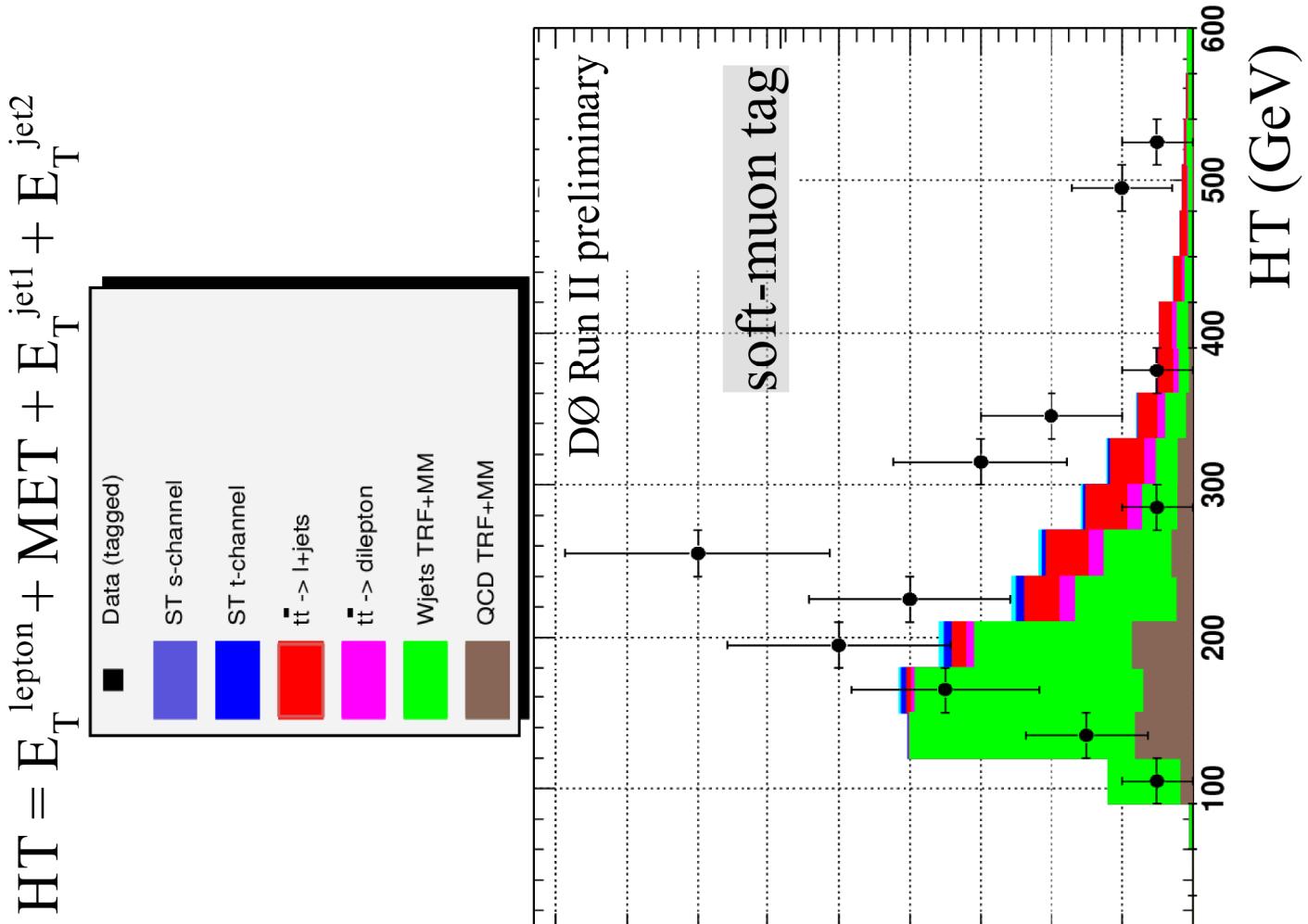
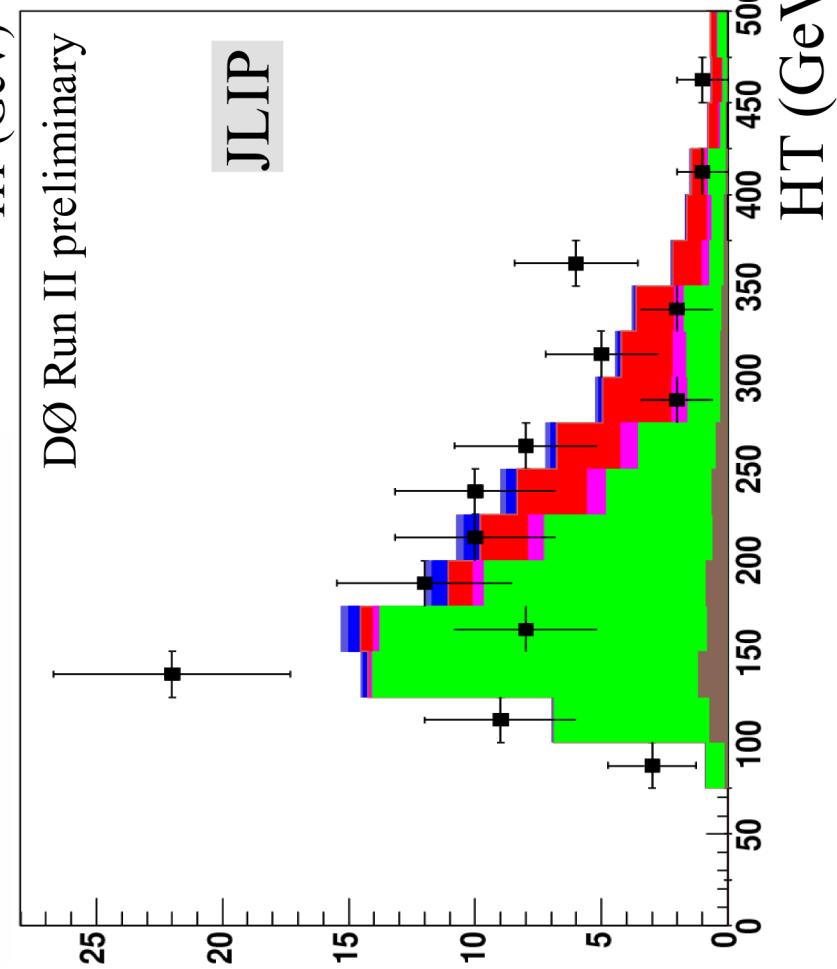
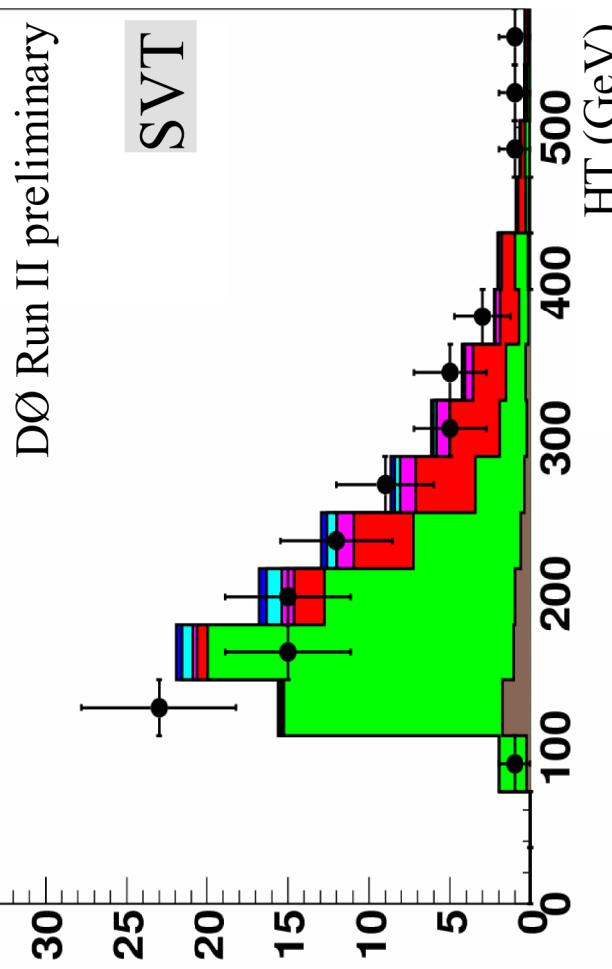
- Lepton: 1 electron,  $p_T > 15\text{GeV}$
- Neutrino: missing  $E_T > 15\text{GeV}$
- Jets:  $2 \leq n \leq 4$ 
  - $p_T > 15\text{GeV}$ , leading jet  $p_T > 25\text{GeV}$
  - $\geq 1$  b-tag
- Trigger Requirement:  $\geq 1$  EM object,  $\geq 1$  jet
- Reject mis-reconstructed events
  - Cosmic ray muons
  - Mis-identified jets
- Triangle cuts



# Event Yields: Number of Jets



# Event Yields: Event Energy HT

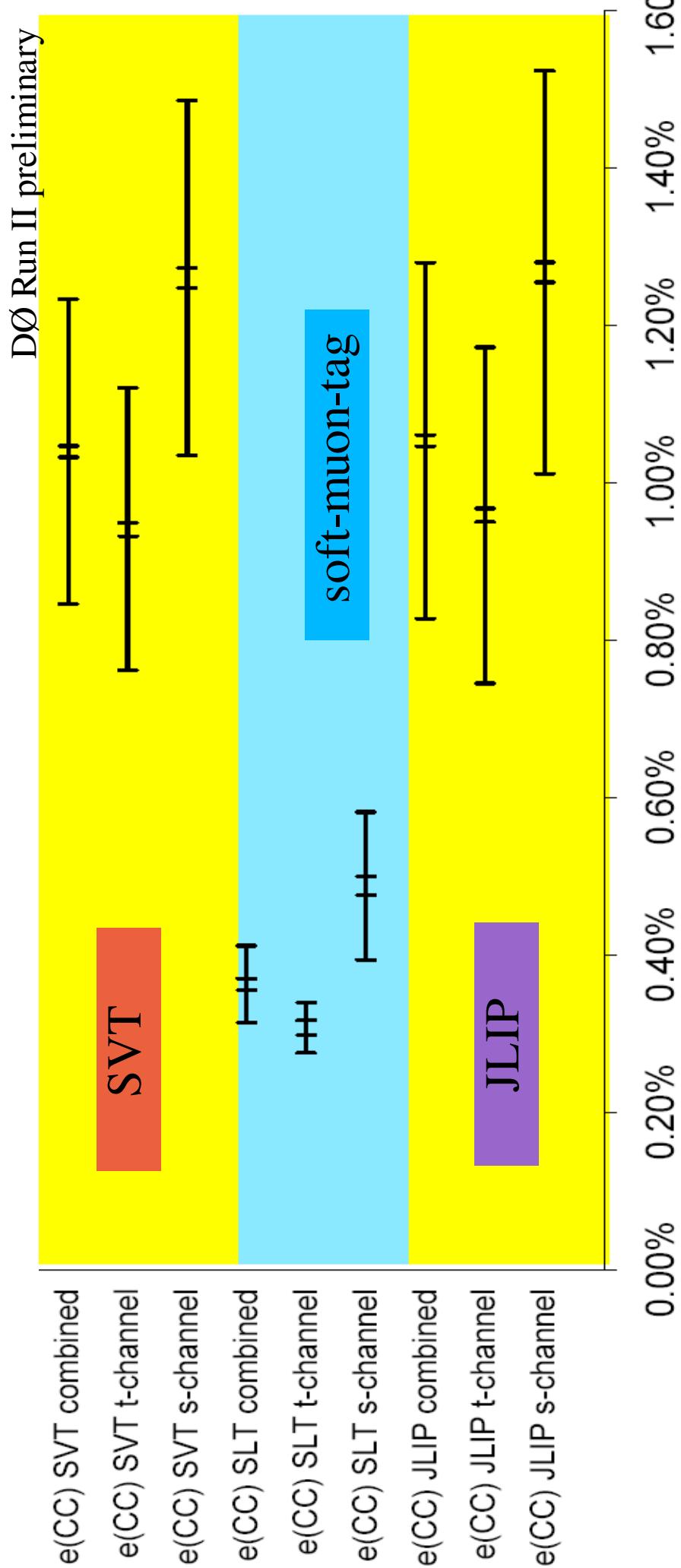


# Final Event Selection

- Dominant background is from W+jets
- Cut on  $\text{HT} > 150\text{GeV}$ 
  - $\text{HT} = E_T^{\text{lepton}} + \text{MET} + E_T^{\text{jet1}} + E_T^{\text{jet2}}$
  - Reduces W+jets background by about 50%
  - Reduces Single Top signal by about 5%
- Systematic Uncertainties
  - Data: largest contribution from determination of tagging probability: ~20%
  - MC: large contributions from
    - Jet-Energy-Scale,
    - Trigger modeling
    - MC flavor-dependent b-tag modeling
    - Combined: ~20%



# Signal Acceptance



# Result

- Final Event Yield
  - based on  $\sim 160\text{pb}$  of D $\mathcal{Q}$  Run II data
  - Soft-muon and secondary vertex tagger combined:  
Sum of backgrounds:  $103 \pm 15$  events  
Observed: 117 events
  - Expected from Single Top:  $6.2 \pm 1.8$  events
- Observation consistent with Background expectation
- Estimate sensitivity: expected cross section limits
  - Modified frequentist approach (CLs method)
  - Include all systematic uncertainties and correlations
  - Set limit separately for s-channel, t-channel, s+t combined
  - Combine tagging methods and electron and muon channels



# Conclusion/Outlook

DØ Run II preliminary

## Expected 95% Cross-Section Limit

s-channel:  $<14\text{pb}$

s+t-channel:  $<16\text{pb}$

t-channel:  $<18\text{pb}$

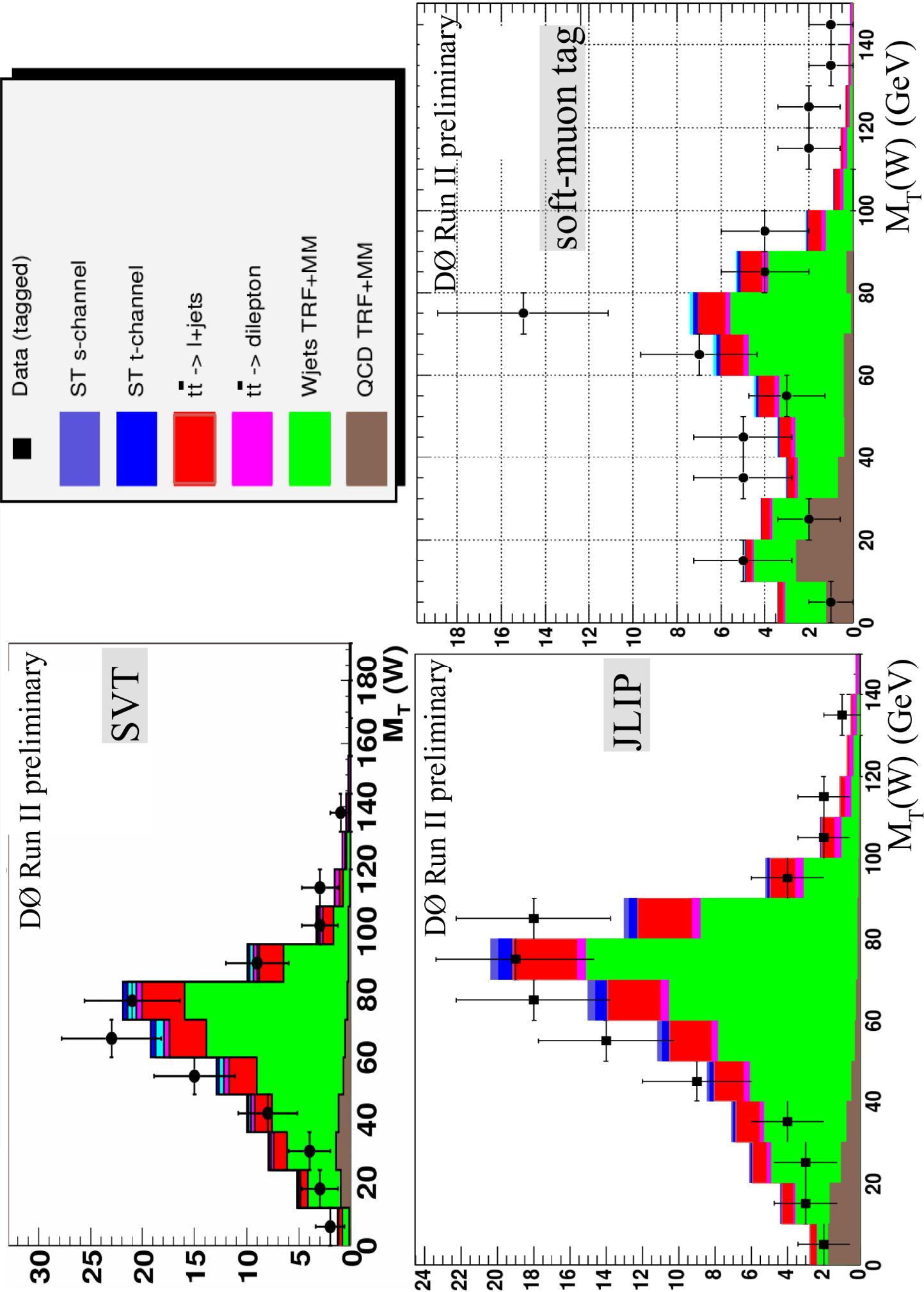
- DØ Run II Single Top Search Program is on its way
- Sensitivity from Run I already exceeded
  - Increased Data Sample
  - DØ detector is performing and understood well
- DØ is working towards observation of single top production
  - Collecting more data
  - Improve detector understanding
  - Improve analysis





# Supporting Slides

# Event Yields: W Transverse Mass



# MC Modeling

## – Single Top modeling: CompHep

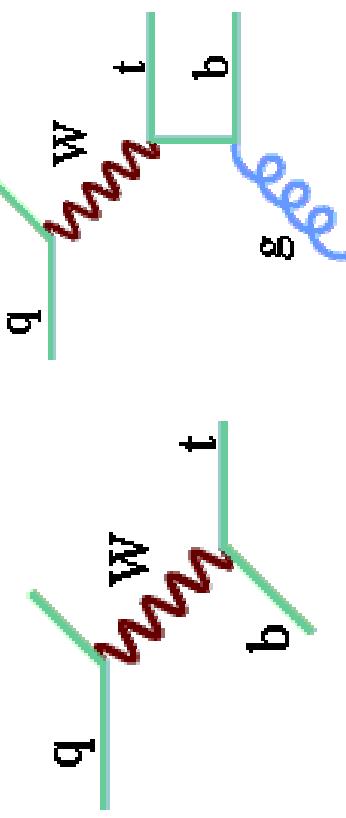
- gives NLO-corrected distributions, not just LO diagrams
- including full spin correlations

## – t-channel problem:

- how to match 2 to 2

with W-gluon fusion

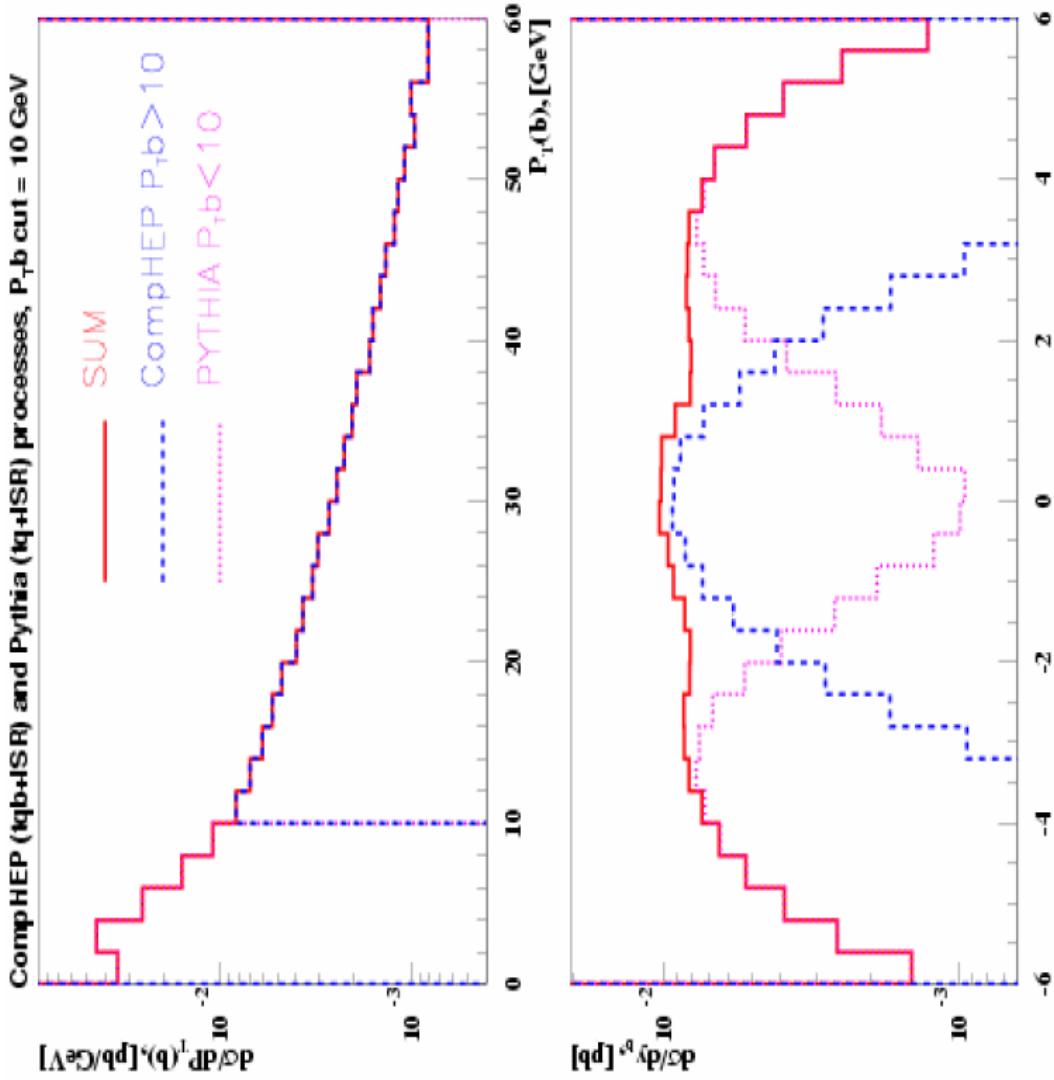
2 to 2      W-gluon fusion



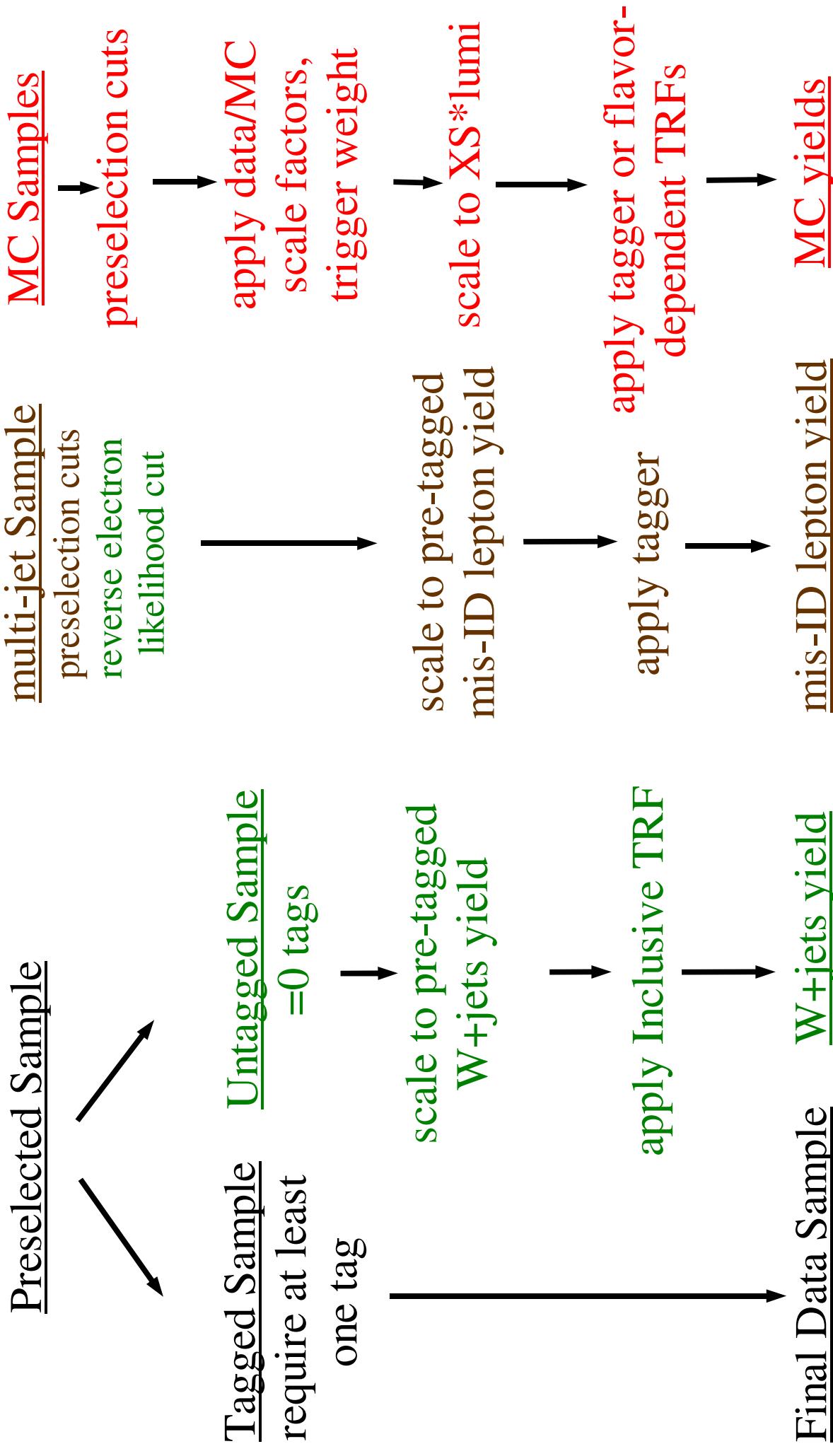
solution:

phase-space matching

- b from Pythia for soft region
- ME generator for hard region



# Background Estimation



# Background Estimate: pre-tagging

- Preselected, Pretagged sample contains two components:
  - Events with *real* isolated lepton
  - Events with *fake* isolated lepton
    - Jet faking an electron
    - Muon in jet faking isolated muon
- Matrix Method to estimate relative contribution
  - Count events before/after a cut that separates the two (loose/tight)
    - Electron channel: electron likelihood cut (combination of cal/tracking)
      - Background efficiency  $e_{QCD}$  determined in multi-jet QCD sample (low MET)
      - Signal efficiency  $e_{sig}$  determined in Zee sample
    - Muon channel: muon isolation from jet
      - Background efficiency  $e_{QCD}$  determined in QCD sample (low MET)
      - Signal efficiency  $e_{sig}$  determined in Zmm sample

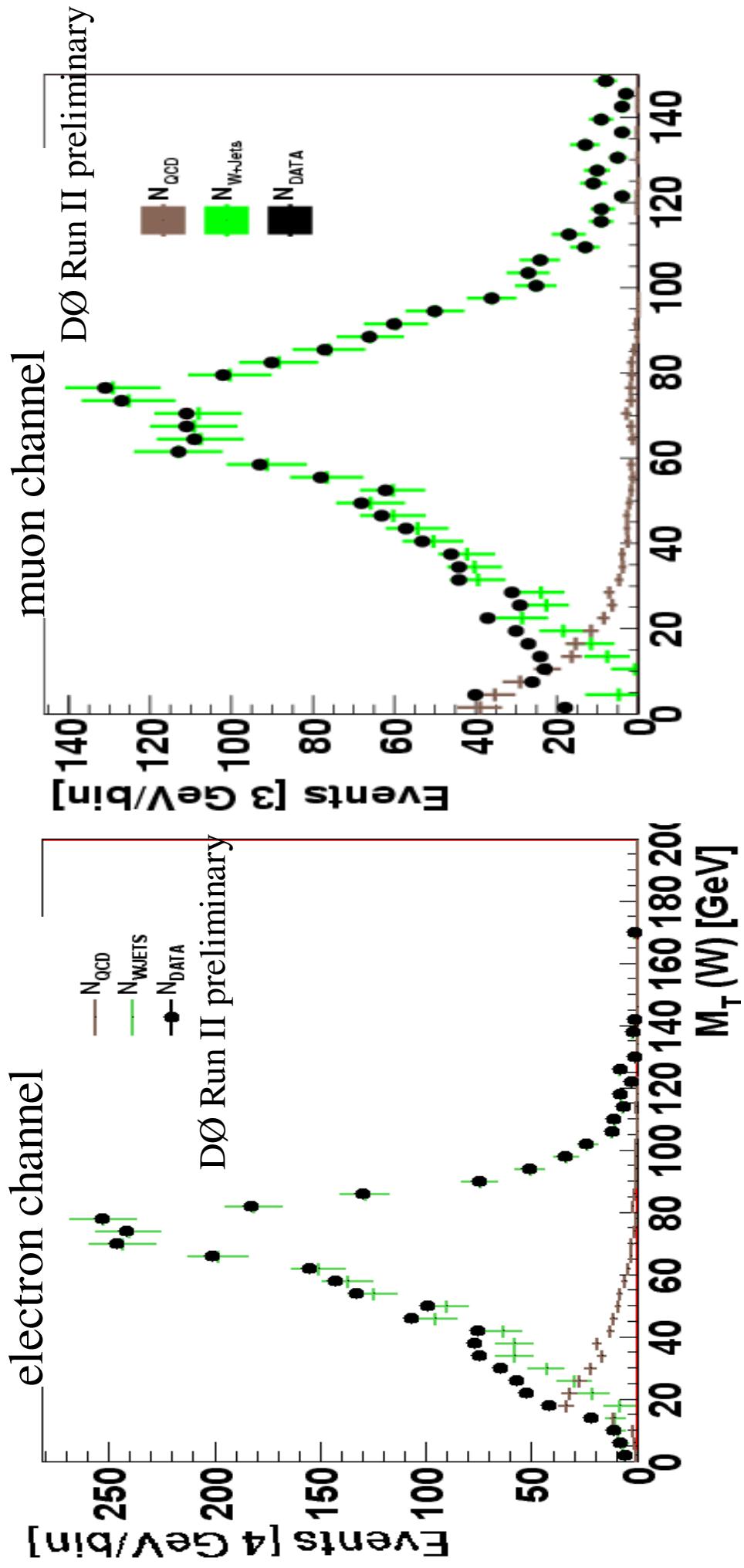


# Pre-tagged Background Yield: W+jets and QCD

$$N_L = \tilde{N}_{sig} + \tilde{N}_{QCD}$$

$$\Rightarrow$$

$$N_T = \epsilon_{sig} \tilde{N}_{sig} + \epsilon_{QCD} \tilde{N}_{QCD}$$



# Background Estimate: tagged

- Data backgrounds: divide preselected sample into orthogonal sets
  - Tagged signal data
    - Require at least one jet to be tagged
  - Un-tagged sample for W+jets background
    - Require that none of the jets be tagged
  - Multi-jet sample with fake isolated leptons for QCD
    - Lepton fails tight cut
  - MC for signal and top pair production background
  - Check prediction in W, QCD-dominated sample
    - Suppress ttbar, single top:
      - $n_{\text{jets}} = 2$
      - total energy in the event  $\text{HT} < 200 \text{GeV}$



# Tag-Rate-Functions

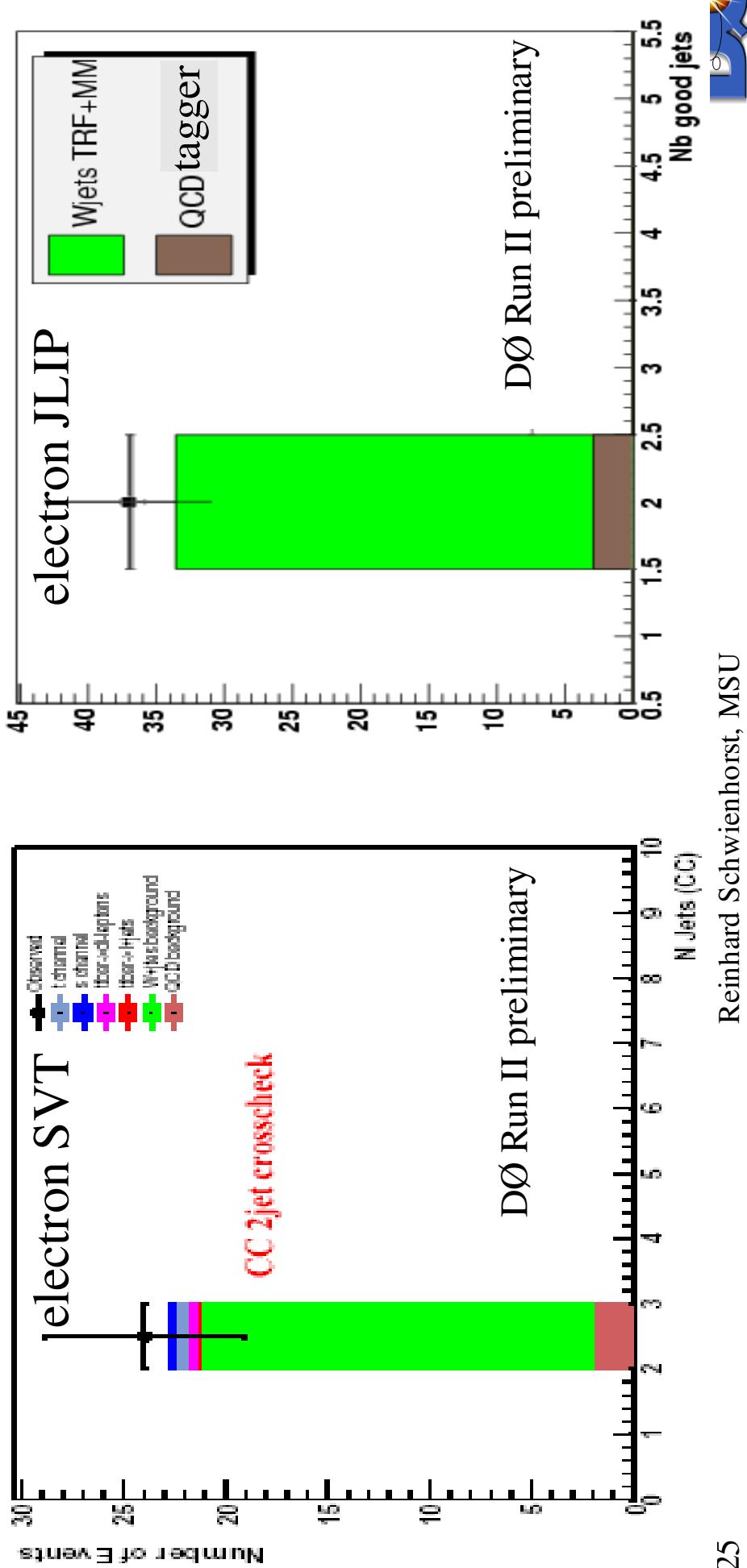
- Flavor-dependent TRF (for b-jets, c-jets, other jets)
  - determined from data with scale factors from MC
  - used to determine tagging-probability in MC events
- Inclusive TRF
  - Used to estimate tagged W+jets background from data
  - Average probability to tag a jet in an inclusive W+jets sample
    - Approximately same as in multi-jet sample
      - Within uncertainty
  - Determine per-jet probability in multi-jet sample ( $=1\text{-}3\%$ )
    - Then apply as weight to each jet in untagged W+jets sample
  - Flavor composition assumption tested in cross-check samples
    - $Z+\geq 2$  jets sample
    - In W+jets cross-check sample ( $n_{\text{jets}}=2$ ,  $\text{HT}<200\text{GeV}$ )
    - Find good agreement in all samples (uncertainty  $\sim 20\%$ )



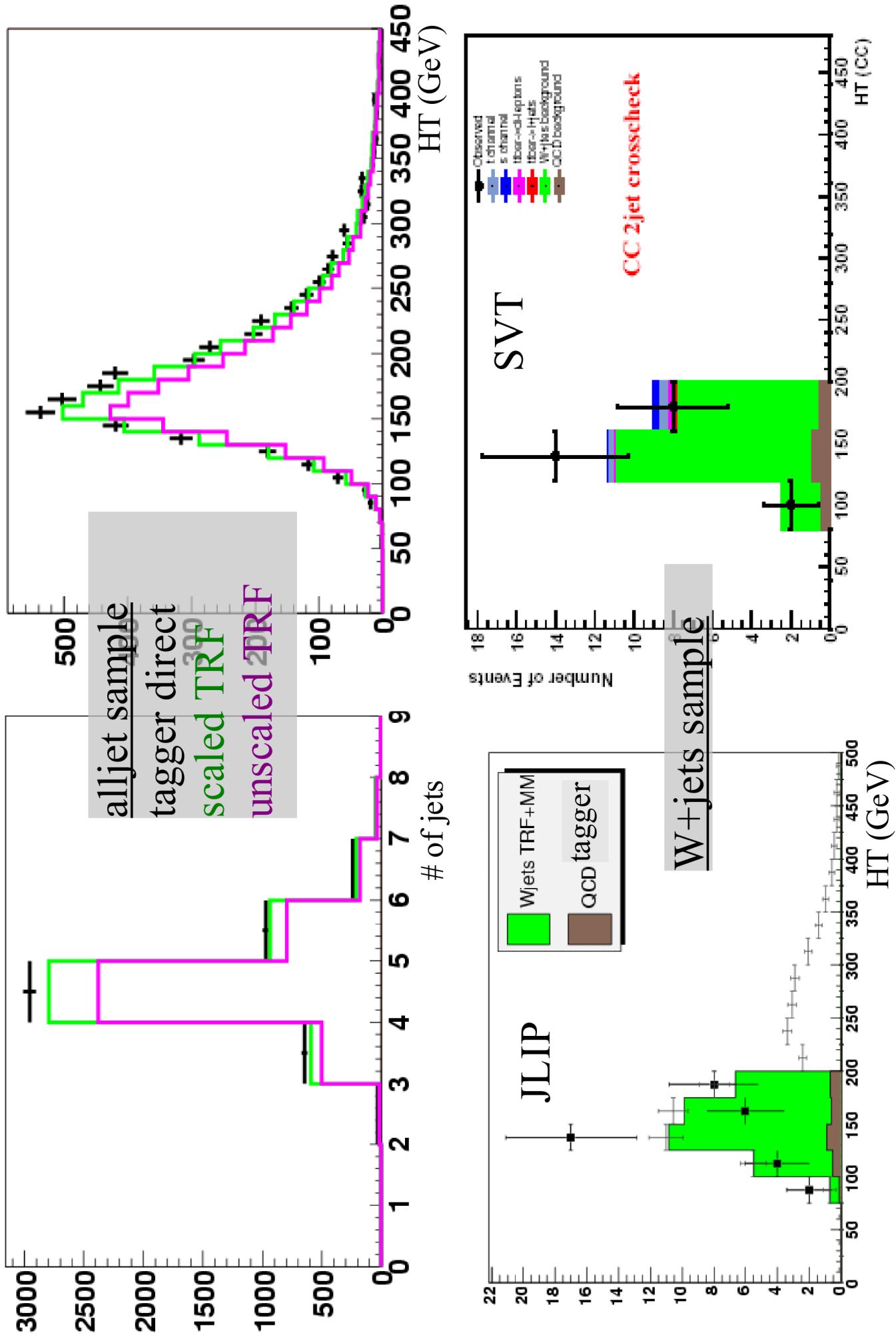
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# Inclusive TRF cross-checks

- $Z+3\text{jet}$  sample:
  - SVT: TRF prediction: 15.7 events, tags found: 17
  - JLI $\text{P}$ : TRF prediction: 14.9 events, tags found: 20
- W cross-check sample
  - muon channel SVT: prediction: 31.6, tags found: 27



# inclusive TRF cross-checks



# Event Yields

	SLT	SVT	JLIP
<b>Signals</b>			
MC $s$ -channel	$0.6 \pm 0.2$	$1.8 \pm 0.4$	$1.8 \pm 0.5$
MC $t$ -channel	$0.9 \pm 0.3$	$2.9 \pm 1.0$	$3.0 \pm 1.1$
<b>MC <math>s+t</math> combined</b>	<b><math>1.6 \pm 0.4</math></b>	<b><math>4.7 \pm 1.4</math></b>	<b><math>4.7 \pm 1.5</math></b>
<b>Backgrounds</b>			
MC $t\bar{t} \rightarrow \ell + \text{jets}$	$7.0 \pm 1.6$	$18.3 \pm 4.4$	$19.2 \pm 5.2$
MC $t\bar{t} \rightarrow \ell\ell$	$2.7 \pm 0.3$	$5.0 \pm 0.8$	$5.2 \pm 1.0$
$W + \text{jets} + \text{fake-}\ell$ data	$24.7 \pm 4.1$	$45.8 \pm 8.9$	$49.7 \pm 9.9$
<b>Sum of backgrounds</b>	<b><math>34 \pm 5</math></b>	<b><math>69 \pm 10</math></b>	<b><math>74 \pm 12</math></b>
<b>Observed data</b>	<b><math>54 \pm 7</math></b>	<b><math>63 \pm 8</math></b>	<b><math>65 \pm 8</math></b>
Acceptance	0.35%	0.97%	0.98%

